US006169776B1

(12) United States Patent
Collins

(10) **Patent No.: US 6,169,776 B1**

(45) **Date of Patent: Jan. 2, 2001**

(54) **METHODS AND APPARATUS FOR EXAMINING A NUCLEAR REACTOR SHROUD**

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(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) Appl. No.: **09/274,051**

(22) Filed: **Mar. 22, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/100,445, filed on Sep. 15, 1998.

(51) **Int. Cl.**[7] **G21C 17/003**; G21C 19/20

(52) **U.S. Cl.** **376/249**; 376/258; 376/260

(58) **Field of Search** 376/245, 249, 376/258, 260

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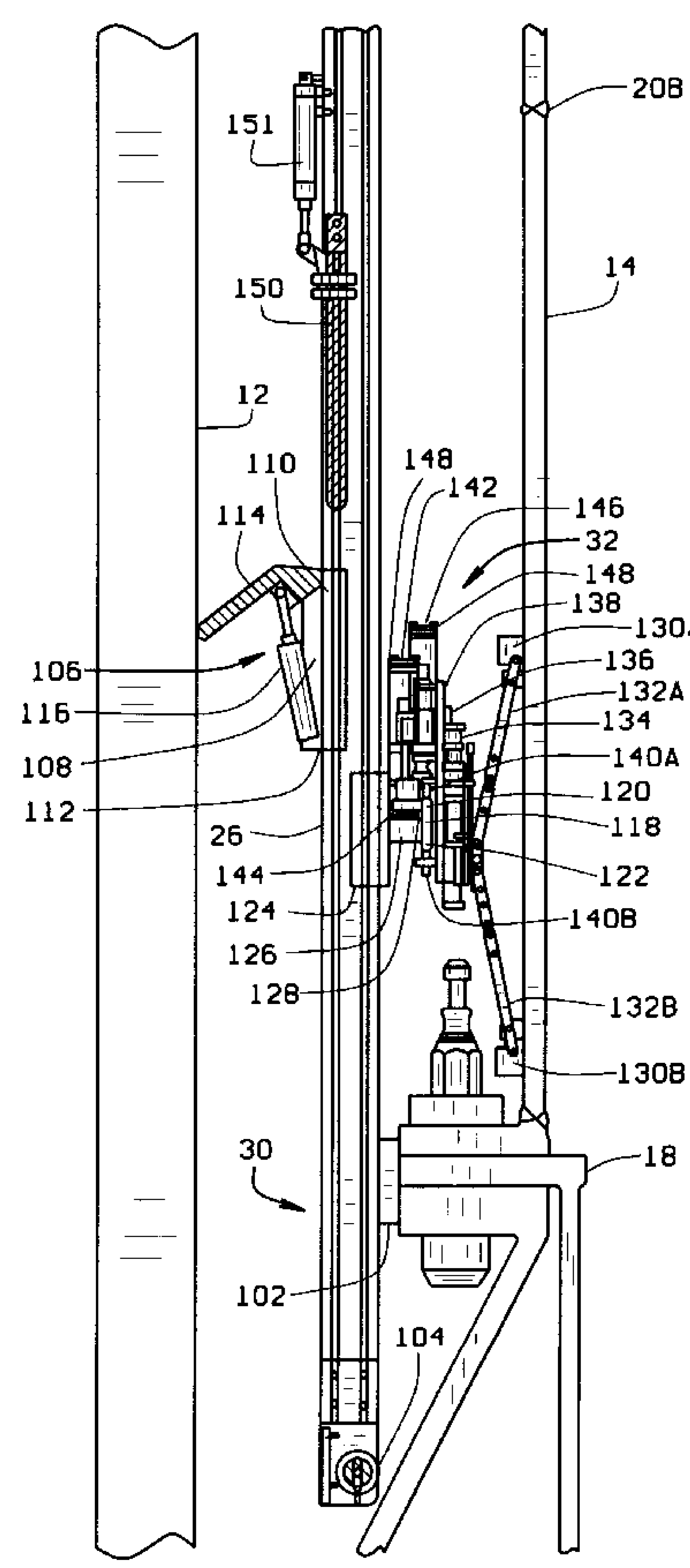
(57) **ABSTRACT**

Methods and apparatus for examining a nuclear reactor shroud are described. In one embodiment the inspection apparatus includes a drive system, a mast subassembly, and a scanner subassembly. The drive system includes at least two drive assemblies that engage the shroud top to move the inspection apparatus relative to the shroud. The mast subassembly is coupled to the drive system and includes a roller foot which engages the shroud bottom flange to prevent movement of the inspection apparatus during scanning of the shroud. The scanner subassembly is movably coupled to the mast subassembly and includes a horizontal frame, a scanner carriage having a turntable, a movable plate and a scanner. The scanner subassembly coupled to the mast subassembly provides the scanner with four degrees of motion.

23 Claims, 7 Drawing Sheets



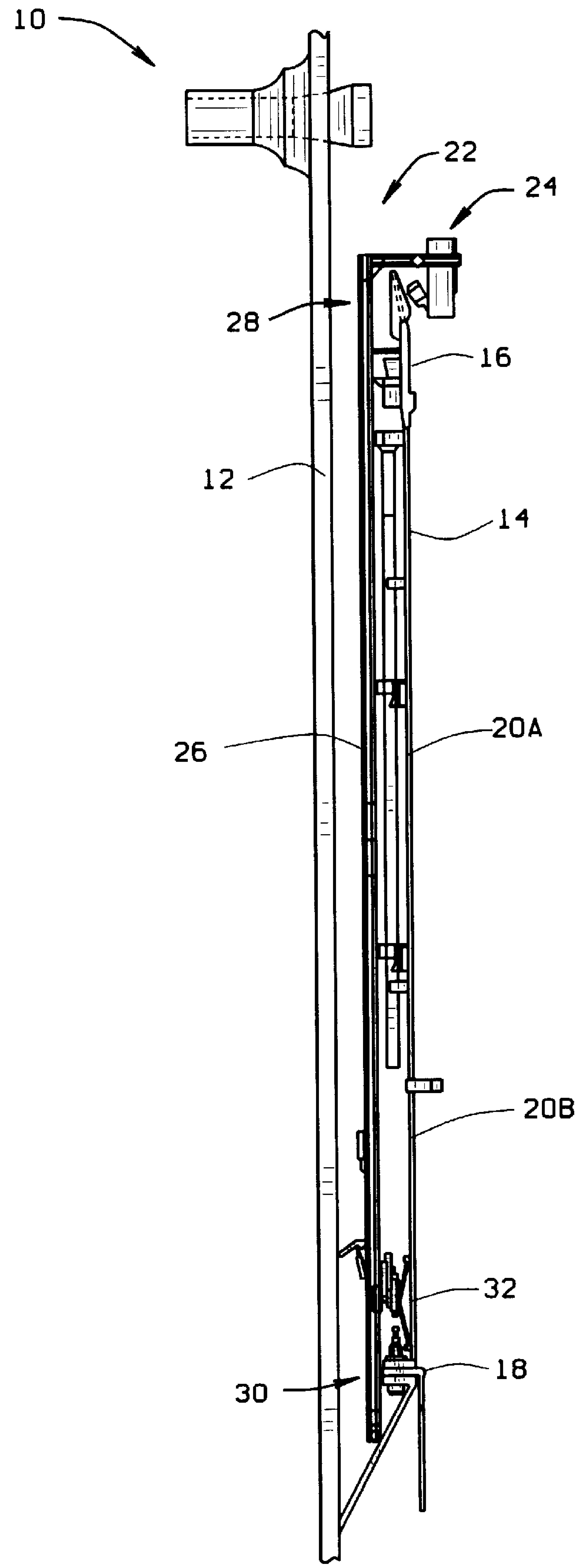
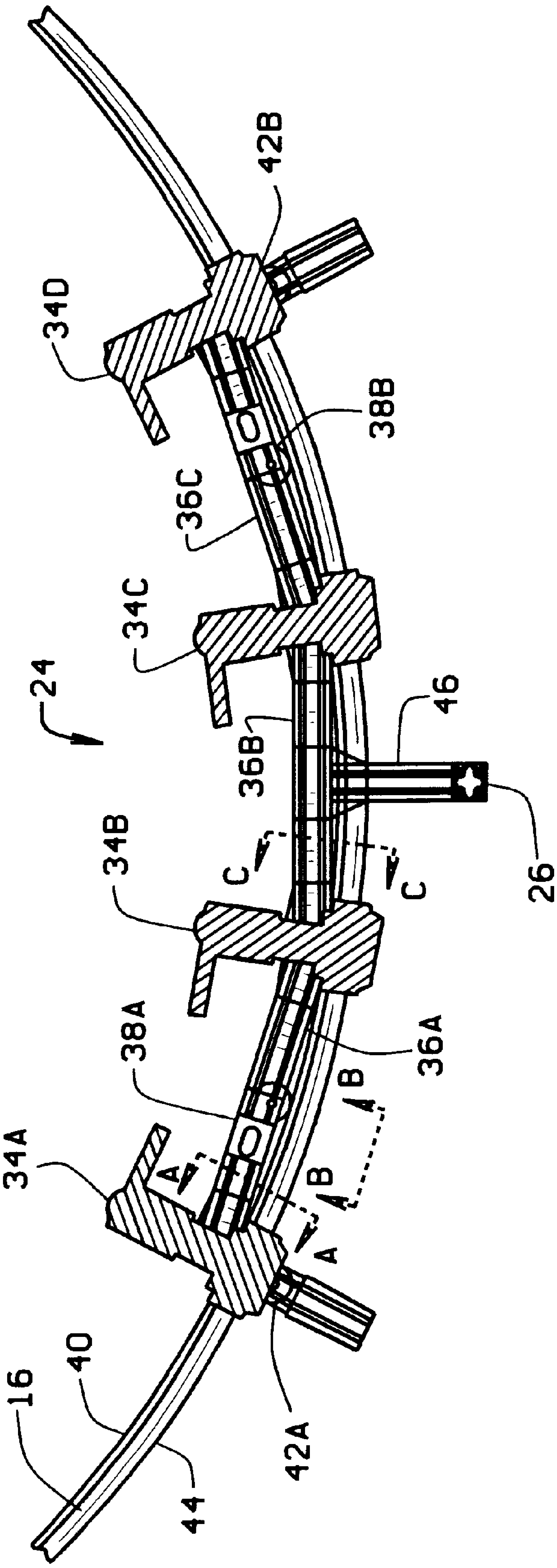


FIG. 1



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38B
36C
34C
24
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16
44
42A

FIG. 2

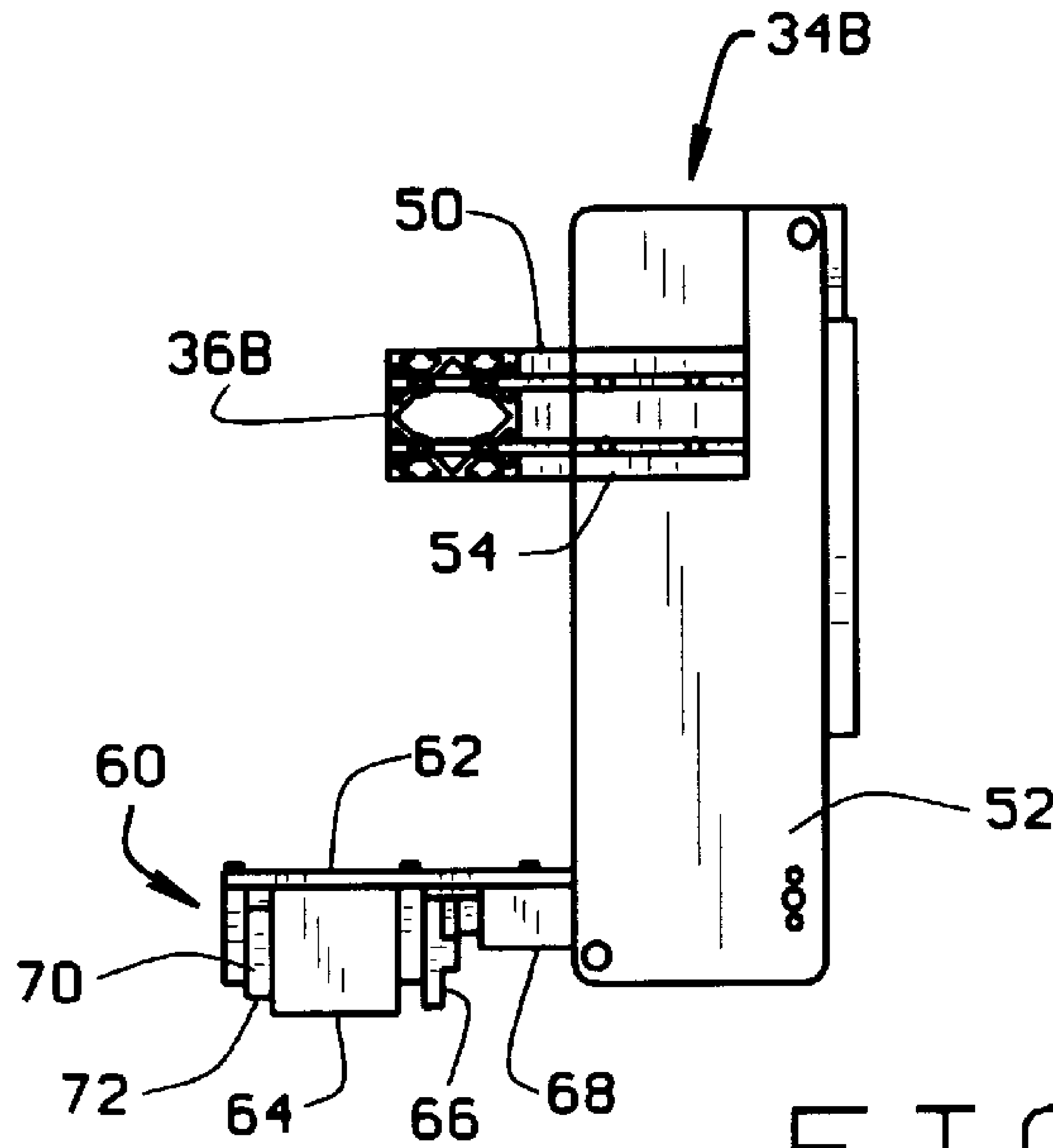


FIG. 3

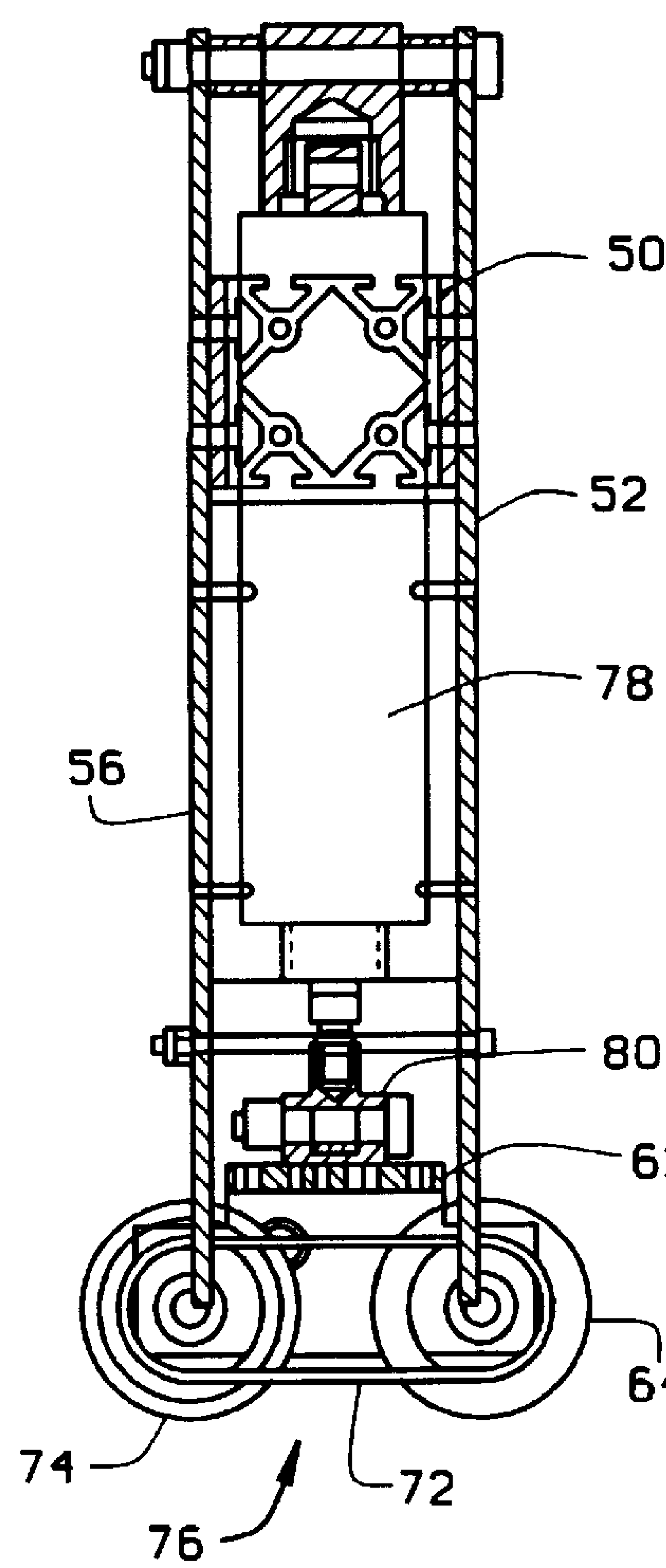


FIG. 4

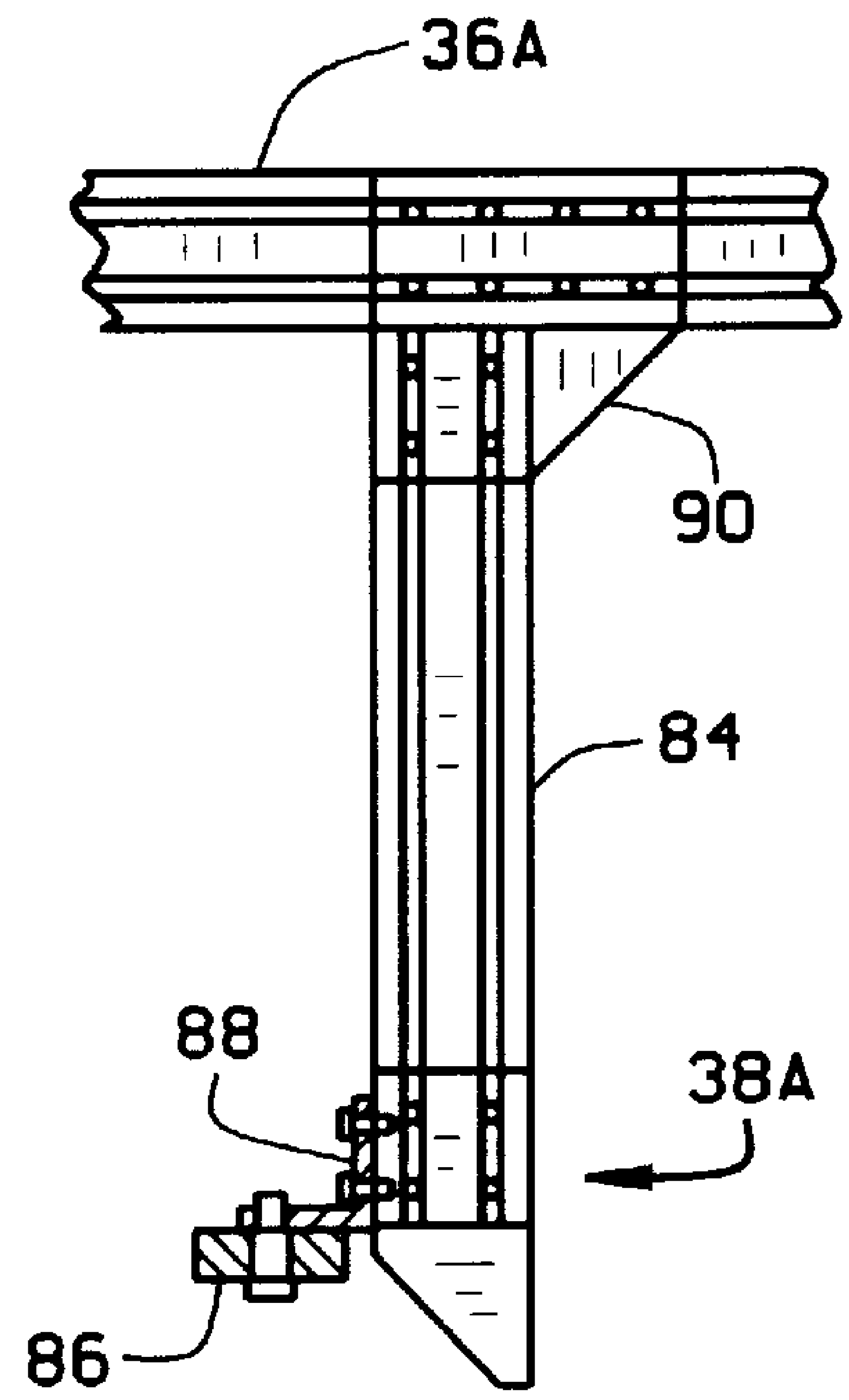


FIG. 5

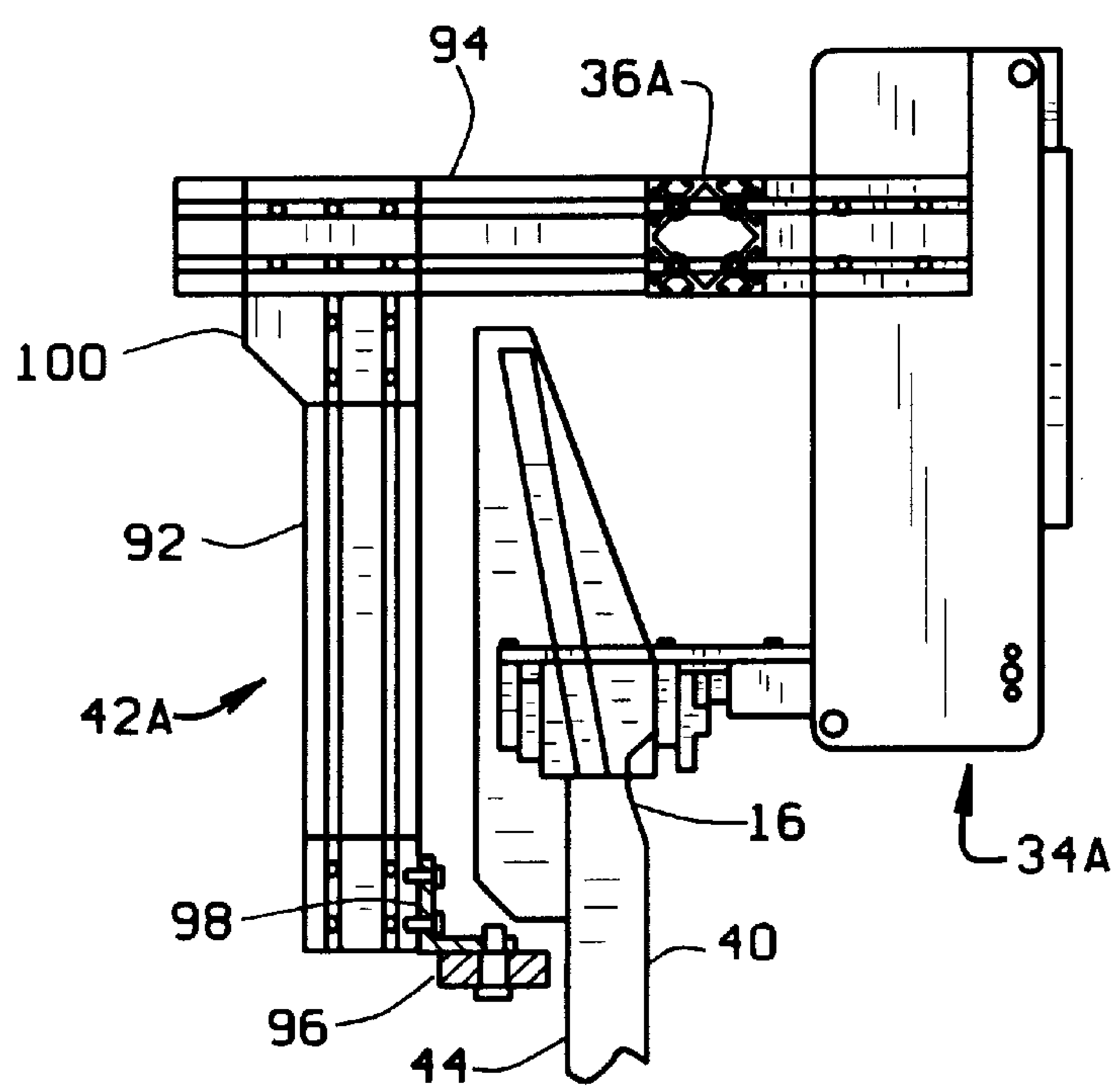
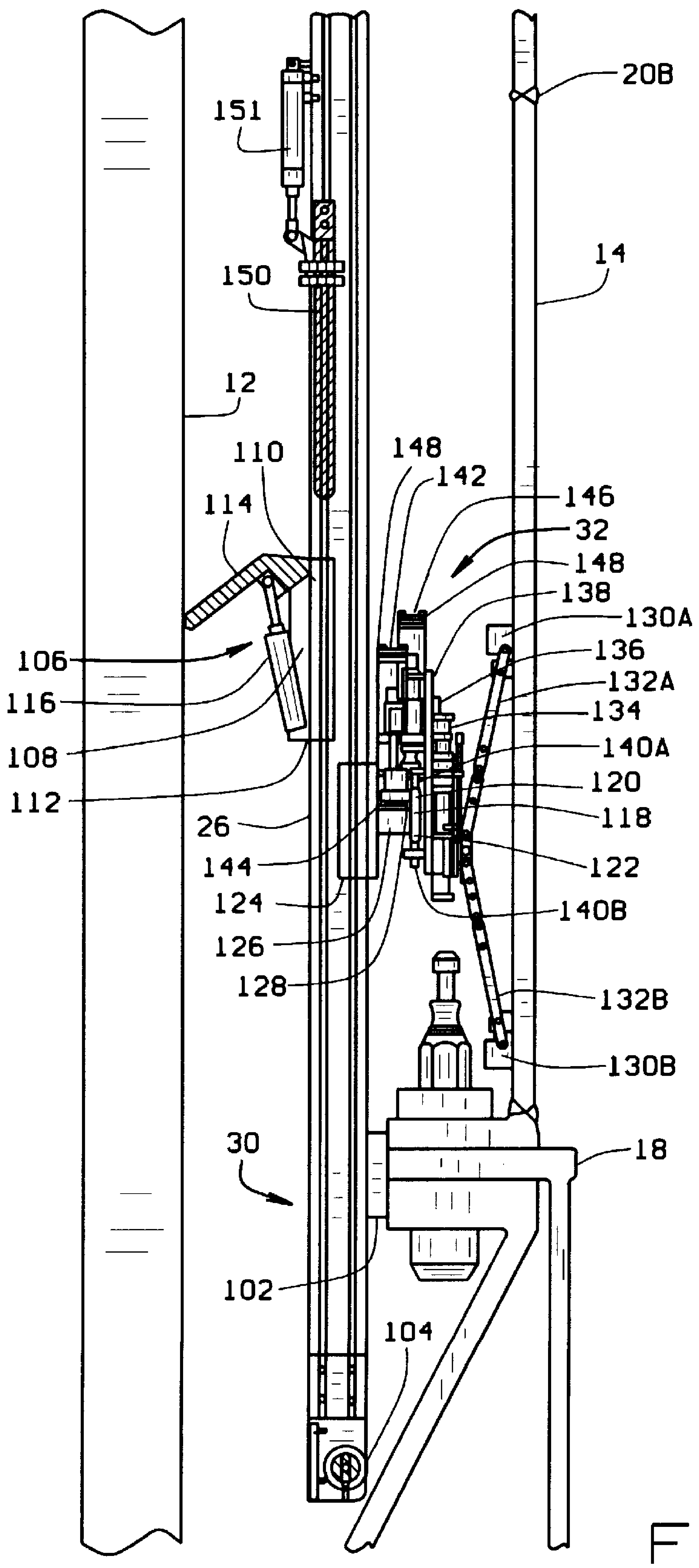


FIG. 6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102
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FIG. 7

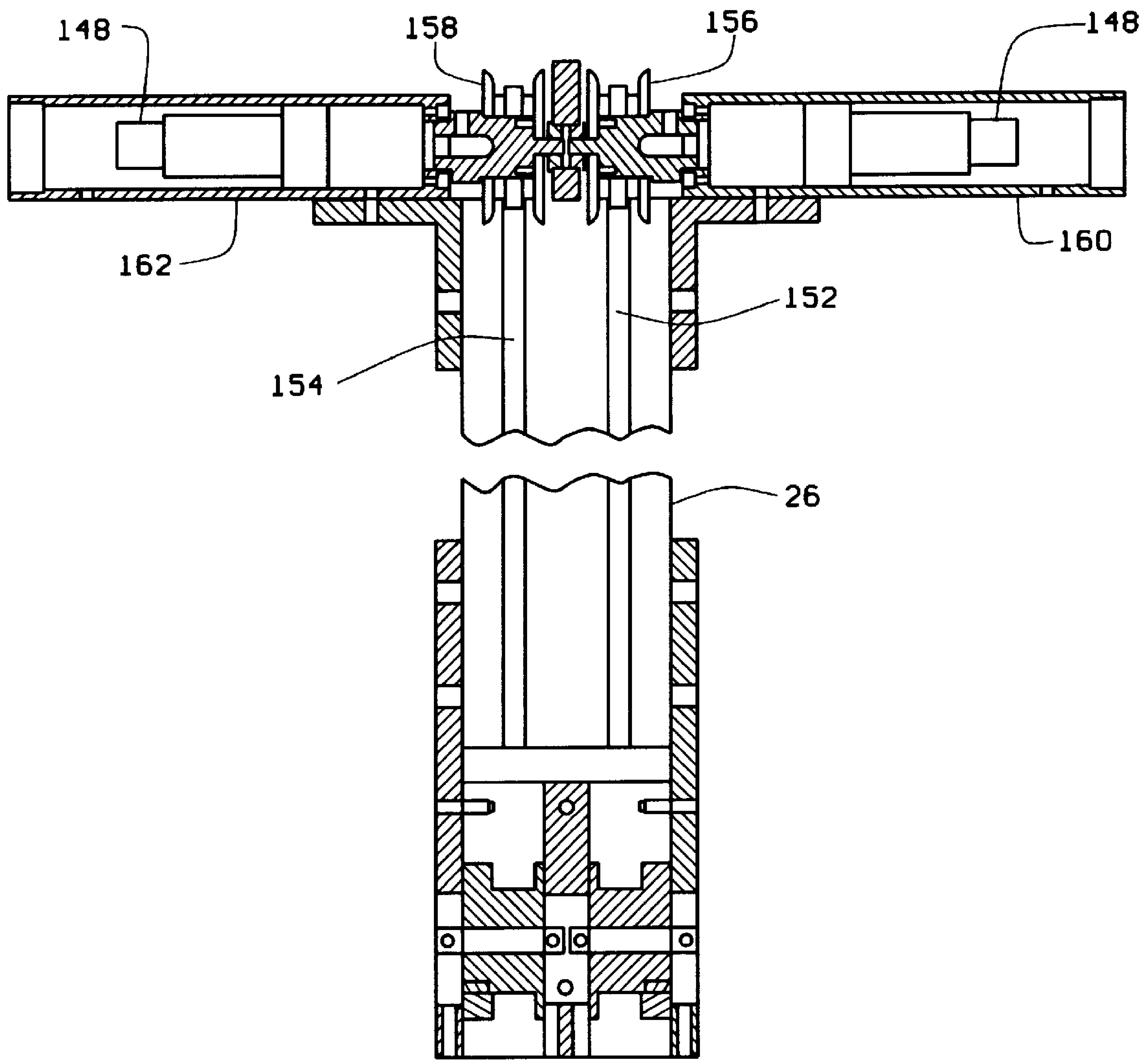

FIG. 8

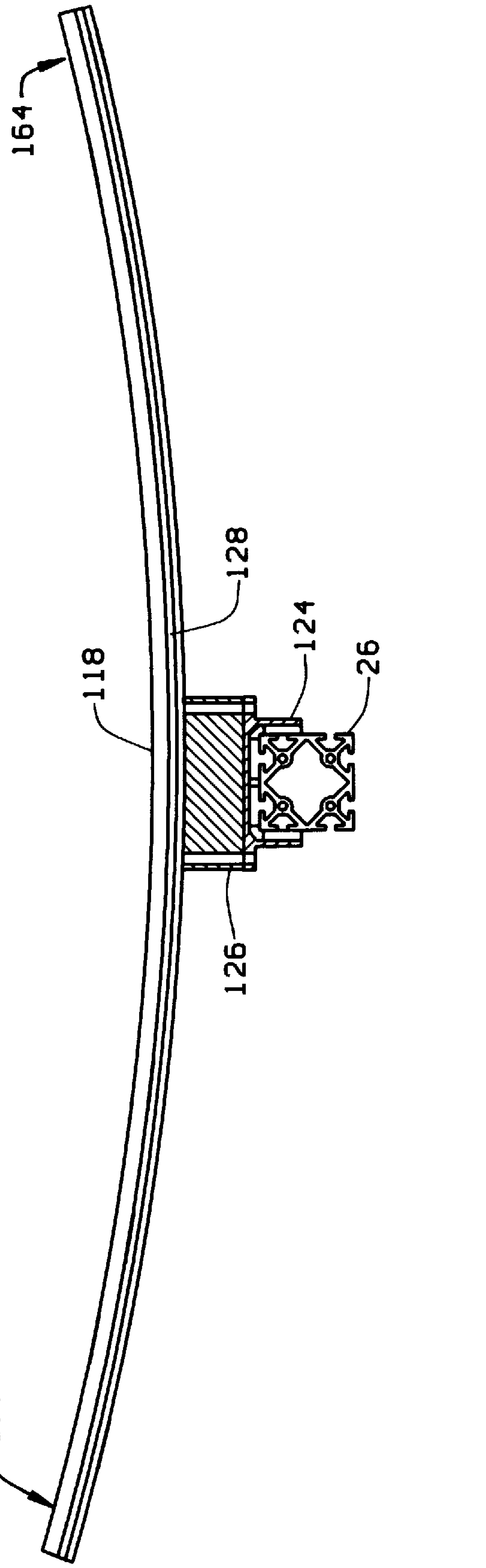

FIG. 9

METHODS AND APPARATUS FOR EXAMINING A NUCLEAR REACTOR SHROUD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/100,445, filed Sep. 15, 1998.

BACKGROUND OF THE INVENTION

A reactor pressure vessel (RPV) of a boiling water reactor (BWR) typically has a generally cylindrical shape and is closed at both ends, e.g., by a bottom head and a removable top head. A top guide typically is spaced above a core plate within the RPV. A core shroud, or shroud, typically surrounds the core and is supported by a shroud support structure. Particularly, the shroud has a generally cylindrical shape and surrounds both the core plate and the top guide.

Intergranular Stress Corrosion Cracking (IGSCC) is a known phenomenon occurring in reactor components, such as structural members, shrouds, piping, fasteners, and welds, exposed to stress in a corrosive environment. Typically, IGSCC initiates from a crevice at the base material along a weld in what is referred to as the heat affected zone. Reactor components are subject to a variety of stresses associated with, for example, differences in thermal expansion, the operating pressure needed for the containment of the reactor cooling water, and other sources such as residual stresses from welding, cold working and other inhomogeneous metal treatments. In addition, water chemistry, welding, heat treatment and radiation can increase the susceptibility of metal in a component to IGSCC.

Over the life of the reactor, the shroud is often inspected to verify integrity. For example, the shroud welds must be periodically inspected for Intergranular Stress Corrosion Cracking (IGSCC). Based upon such inspections, the shroud may require either repair or replacement.

Known methods of inspecting shroud welds require an operator to stand on a refuel or auxiliary bridge positioned above the RPV and to manipulate inspection tooling within the RPV. Particularly, the operator couples the inspection tooling to a pole, inserts the pole and tooling into the RPV, and then positions the tooling adjacent to the weld to be examined. Because different inspection tooling is required to inspect different welds, i.e., vertical, attachment, and circumferential welds, the operator must periodically change the tooling coupled to the pole. In addition, due to the reactor internals configuration and the piping system obstructions, the operator typically must make extensive use of the bridge to inspect each shroud weld. This extensive bridge use substantially prevents other repair and inspection operations from being conducted simultaneously with the weld inspections.

It would be desirable to provide a shroud inspection apparatus particularly suitable for use in nuclear reactor applications which is easy to use and does not require support from the refuel or auxiliary bridge for performing shroud inspections. It would also be desirable to provide such an apparatus which minimizes the number of insertions, removals, and tooling change-out sequences to facilitate reducing reactor shut-down time. It would further be desirable to provide such an apparatus which navigates around anticipated shroud obstructions to facilitate reducing inspection time and operator activity.

BRIEF SUMMARY OF THE INVENTION

These and other objects may be attained by an inspection apparatus which, in one embodiment, inspects a shroud,

specifically shroud welds, in a nuclear reactor. The inspection apparatus includes a drive system having four drive assemblies coupled to three support frame members. Each drive assembly includes dual cylindrically shaped drive wheels sized to rest on the shroud and move the inspection apparatus relative to the shroud. Each drive wheel pair independently moves between a position resting on the shroud top and a position rotated up and away from the shroud top. The drive assembly is maintained in proper radial position by inner and outer guide rollers. The inner guide rollers ride along the inner surface of the upper shroud circumference and the outer guide roller ride along the outer surface of the upper shroud circumference.

The inspection apparatus also includes a mast subassembly and a scanner subassembly. The mast subassembly includes a substantially elongate member and a roller foot coupled to the elongate member second end. The mast subassembly elongate member first end is coupled to the drive system support frame. The scanner subassembly has a substantially elongate horizontal frame, a scanner carriage having a turntable, and an ultrasonic scanner. The horizontal frame is movably coupled to the mast subassembly elongate member.

The vertical position of the scanner subassembly is changed by moving the horizontal frame between the ends of the mast subassembly. The horizontal position of the scanner is controlled by movement of the scanner carriage between the horizontal frame ends. The turntable rotatably couples the scanner to the scanner carriage. The scanner additionally has a fine vertical movement on the scanner carriage. The four degrees of motion allows the scanner subassembly to perform volumetric examinations of circumferential, vertical, and attachment shroud welds.

Additionally, the inspection apparatus includes an umbilical control system which uses gravity to feed an umbilical cable to a proper position along side the mast and couples the scanner subassembly and a data collection system. The umbilical control system maintains an appropriate amount of umbilical cable between the data collection system and the scanner subassembly.

To scan the shroud, and more specifically, the shroud welds, the inspection apparatus is lowered into the RPV until the drive system drive wheels rest on the shroud top. The mast subassembly is then positioned adjacent to the shroud so that the mast subassembly roller foot is tangent to the shroud. The drive assembly wheel and mast subassembly, including the roller foot, clamp the inspection apparatus to the shroud with the aid of a kicker clamp. The kicker clamp extends from the mast and engages the RPV wall which causes the bottom roller foot to engage the shroud and provides a fixed rigid structure from which to perform shroud inspections. This rigidity ensures no wandering of the inspection apparatus resulting from frictional forces during scanner subassembly motion to help reduce azimuthal positioning errors.

Once the inspection apparatus is clamped in position, the scanner subassembly scans the shroud welds. Particularly, in one embodiment, the scanner subassembly is moved adjacent to the mast subassembly first end with the scanner carriage adjacent the horizontal frame first end. The scanner carriage is then moved between the first and second ends of the horizontal frame as the scanner performs a complete scan for each weld. The horizontal frame is then moved toward the mast subassembly second end a distance equal to the height of the completed scan. The fine vertical movement can then be used to precisely control the vertical position of the scanner. This scan procedure is repeated until the horizontal frame is adjacent to the mast subassembly second end. The mast subassembly kicker clamp is then retracted away from the RPV wall and the drive system moves the inspection apparatus relative to the shroud a distance equal to the width of the horizontal frame. This scan procedure is repeated until the inspection apparatus encounters an obstruction at the shroud top or the entire shroud has been scanned.

If the drive system encounters an obstruction, the obstruction must be avoided or stepped around. In stepping around the obstruction, one of the drive assemblies currently retracted from the shroud is moved so that the drive wheels rest on the shroud top. The drive assembly encountering the obstruction is then moved so that the drive wheels are rotated inward away from the shroud. As a result, the inspection apparatus may be moved relative to the shroud.

Should the inspection apparatus encounter the obstruction with a second drive assembly, a drive assembly retracted from the shroud can be placed on the shroud top and the drive assembly currently encountering the obstruction is rotated inward away from the shroud. This stepping around process is repeated as each drive assembly encounters the obstruction. Additionally, due to the spacing of the drive assemblies on the support frame only two drive assemblies are necessary to support and move the inspection apparatus. Therefore the inspection apparatus can avoid two simultaneous obstructions as long as two of the four drive assemblies are resting on the shroud top.

Upon completion of scanning the entire shroud, the inspection apparatus is removed from the RPV. Specifically, the kicker clamp is disengaged from the RPV wall. The inspection apparatus is then lifted until the mast subassembly is above the shroud top and then removed from the RPV. The resulting scan data is analyzed to determine any necessary maintenance activities.

The above-described apparatus facilitates inspection of a nuclear reactor shroud without requiring support from the refuel or auxiliary bridge. In addition, such inspection apparatus avoids shroud top obstructions allowing examination of the entire shroud with a single insertion and removal of the inspection apparatus, therefore saving time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cut away side view of a nuclear reactor pressure vessel with an inspection apparatus resting on a shroud.

FIG. **2** is a top view of the inspection apparatus shown in FIG. **1**.

FIG. **3** is an exploded side view of a drive assembly.

FIG. **4** is an exploded front view of the drive assembly shown in FIG. **3**.

FIG. **5** is an exploded side view of a guide wheel assembly.

FIG. **6** is an exploded side view of a guide wheel assembly and drive assembly with a drive wheel engaging the shroud top.

FIG. **7** is an exploded view of the lower part of FIG. **1**.

FIG. **8** is a back view of the vertical drive assembly.

FIG. **9** is a cut away top view of the horizontal inspection apparatus illustrating the horizontal frame member.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a cut away side view of a reactor pressure vessel **10** including a sidewall **12** and a shroud **14** having a shroud top **16**, a shroud bottom flange **18**, and welds **20**A and **20**B. Shroud **14** may contain many welds extending both vertically and horizontally. Welds **20**A and **20**B are shown for exemplary purposes. Intergranular Stress Corrosion Cracking (IGSCC) inspection of shroud welds **20**A and **20**B is completed using an inspection apparatus **22**. Inspection apparatus **22** includes a drive system **24**, a mast subassembly **26** and a scanner subassembly **32**. Mast assembly **26** has a first end **28** and a second end **30**.

Referring to FIG. **2**, drive system **24** includes drive assemblies **34**A, **34**B, **34**C, and **34**D. Support frame member **36**A extends between and is coupled to drive assemblies **34**A and **34**B. Support frame member **36**B extends between and is coupled to drive assemblies **34**B and **34**C. Support frame member **36**C extends between and is coupled to drive assemblies **34**C and **34**D. Guide roller assemblies **38**A and **38**B are coupled to support frame members **36**A and **36**C respectively. Guide roller assemblies **38**A and **38**B are configured to contact and roll along an inside surface **40** of shroud **14**. Guide roller assemblies **42**A and **42**B are coupled to support frame members **36**A and **36**C respectfully at the location where drive assemblies **34**A and **34**D are coupled to drive system **24**. Guide roller assemblies **42**A and **42**B are configured to contact and roll along the outside surface **44** of shroud **14**. Mast support member **46** extends between and is coupled to frame support member **36**B and to first end **28** of mast **26**.

Referring to FIGS. **3** and **4**, FIG. **3** is an exploded side view of drive assembly **34**B along line C—C of FIG. **2**. FIG. **4** is an end view of drive member **34**B. Drive assemblies **34**A, **34**C and **34**D are identical to drive assembly **34**B, and are therefore not shown. Drive support channel member **50** extends from and is coupled to support frame member **36**B. Drive assembly plate **52** is coupled to the side of drive support channel member **50**. Support bracket **54** overlies and is coupled to plate **52** and support member **50** for added support. A second drive assembly plate **56** (shown in FIG. **4**) is coupled to an opposing side of drive support channel member **50**. Drive wheel assembly **60** is pivotly attached to plate **52**. Roller assembly **60** includes wheel mounting plate **62** and drive wheel **64** which is substantially cylindrically shaped and configured to ride on shroud top **16**. Spur gear **66** couples wheel **64** to motor **68** at a first end of wheel **64**. Timing belt pulley **70** is located at a second end of wheel **64**. Timing belt **72** engages pulley **70** and couples wheel **64** with wheel **74**. Drive wheels **64** and **74** form a drive wheel pair **76**. Drive assemblies **34**A, **34**C, and **34**D each contain a drive wheel pair **76**. Mounting plate **62** is connected to air ram **78** through swivel block **80**. The motion of air ram **78** causes wheel pair **76** to rotate into and out of engagement with shroud top **16**.

FIG. **5** is an exploded side view of guide roller assembly **38**A along line B—B of FIG. **2**. Guide roller **38**B is identical to guide roller **38**A, and therefore is not shown. Guide roller assembly **38**A includes support member **84** extending from and coupled to frame support member **36**A. Roller **86** is coupled to the end of support member **84** through an L-shaped bracket **88**. Support bracket **90** overlies and is coupled to frame support member **36**A and support member **84** for added support.

FIG. **6** is an exploded side view of drive assembly **34**A and guide roller assembly **42**A along line A—A of FIG. **2**. Roller assembly **42**A includes support members **92** and **94** connected to form an L-shaped support. Support member **94** is coupled to frame support member **36**A. Wheel **96** is coupled to the bottom of support member **92** with an L-shaped bracket **98**. A support bracket **100** overlies and is coupled to support member **92** and **94** for added support and rigidity.

Referring to FIG. **7**, a roller foot **102** is coupled to mast **26** at end **30** and is configured to contact and roll along shroud bottom flange **18**. A kicker clamp **106** is coupled to mast **26** by a mounting bracket **108** having a first end **110** and a second end **112**. A kicker clamp engagement arm **114** is pivotly coupled to bracket end **110**. An air ram **116** extends between and is coupled to bracket end **112** and engagement arm **114**. When air ram **116** is activated, it causes engagement arm **114** to move into engagement with reactor pressure vessel sidewall **12**.

A horizontal frame member **118**, having an upper portion **120** and a lower portion **122**, is connected to a slidable mounting bracket **124** by a horizontal frame connecting member **126**. Slidable mounting bracket **124** slidably couples horizontal frame member **118** to mast **26** so that horizontal frame member **118** can move between mast first end **28** and mast second end **30**. A gear rack **128** is attached to upper portion **120** of horizontal frame member **118**.

Scanner subassembly **32** includes transducers **130**A and **130**B coupled to transducer mounting arms **132**A and **132**B respectfully. Transducer mounting arms **132**A and **132**B extend from a movable mounting plate **134**. Movable mounting plate **134** is movably coupled to a turntable **136**. Turntable **136** is rotatably coupled to scanner mounting plate **138**.

Rollers **140**A and **140**B are coupled to scanner mounting plate **138** and are configured to engage horizontal frame member **118**. Roller **140**A engages horizontal frame member upper portion **120** and roller **140**B engages horizontal frame member lower portion **122**.

A drive motor **142**, coupled to scanner mounting plate **138**, includes a drive gear **144** configured to engage gear rack **128**. Scanner subassembly also includes turntable motor **146**.

Drive motors **142**, **146**, and **68** (shown in FIG. **3**) are servo-control type motors. Servo-control motors provide closed loop feedback through encoders **148** coupled to motors **142**, **146**, and **68**. Encoders **148** count the revolutions of motors **142**, **146**, and **68**. The revolutions can then be converted to a linear movement that corresponds to a true position of transducers **130**A and **130**B.

A kicker arm **150** is coupled to mast **26**. An air ran **151** pivots kicker arm **150** out and into engagement with sidewall **12** to guide apparatus **22** during installation in pressure vessel **10**.

Referring to FIG. **8**, drive belts **152** and **154** are engaged by drive sprockets **156** and **158** respectively. Drive motors **160** and **162** are coupled to drive sprockets **156** and **158** respectively. Drive belts **152** and **154** extend down mast **26** and around pulley **104** (shown in FIG. **7**). Drive belt **152** is attached to horizontal frame member **124** (shown in FIG. **7**) and provides vertical movement for horizontal frame member **118** (shown in FIG. **7**). Drive belt **154** is coupled to a camera (not shown) that is configured to move up and down mast **26** to provide an operator on the spot vision of scanner subassembly **32**. Encoders **148** are coupled to drive motors **160** and **162** to provide position information.

Referring to FIG. **9**, horizontal frame member **118** includes a first end **164** and a second end **166**. Gear rack **128** is attached to horizontal frame member **118** and is positioned to face mast **26** so as to engage drive gear **144** (shown in FIG. **7**).

In operation, inspection apparatus **22** is inserted into reactor pressure vessel **10** so that drive system **24** engages shroud **14**. Specifically, drive assemblies **34**A, **34**B, **34**C, and **34**D engage shroud top **16** with guide rollers **38**A and **38**B engaging shroud inner surface **40** and guide rollers **42**A and **42**B engaging shroud outer surface **44**. Roller foot **102** is then moved into engagement with shroud bottom flange **18** by activating air ram **116** which causes kicker clamp engagement arm **114** into engagement with reactor pressure vessel sidewall **12**. The engagement of arm **114** against sidewall **12** causes mast **26** to move towards shroud **14** until roller foot **102** engages shroud bottom flange **18**. Drive system **24** and mast subassembly **26**, including roller foot **102** and kicker clamp **106**, clamp inspection apparatus **22** to shroud **14**. This clamping provides rigidity to hold inspection apparatus **22** in position, ensuring no wandering of apparatus **22** caused by frictional forces during scanner subassembly **32** motion.

After clamping inspection apparatus **22** in position, shroud weld **20**A can be inspected. Scanner subassembly **32** is first positioned adjacent to shroud weld **20**A using motor **160**. Specifically, vertical drive motor **160** using belt **152** moves horizontal frame member **118** so that scanner assembly **32** is positioned adjacent to shroud weld **20**A. Scanner assembly **32** is then moved to horizontal frame first end **164**. A first scan then begins by scanning shroud weld **20**A as scanner assembly **32** scans an area of weld **20**A. Scanner data is transmitted through an umbilical cable (not shown), that extends along mast **26**, to a remote data collection system (not shown). After the first area is scanned, turntable **135** rotates transducers **130**A and **130**B so that weld **20**A can be scanned from various angles. Upon scanning a weld first area at all required angles, resulting in a volumetric scan, scanner assembly **32** is then repositioned over an adjacent area of shroud weld **20**A by moving scanner assembly **32** towards horizontal frame second end **166**. Scanner assembly **32** continues scanning each location along weld **20**A until scanner assembly **32** reaches horizontal frame second end **166**. Upon reaching second end **166**, vertical motor **160** moves scanner assembly **32** adjacent weld **20**B. In one embodiment, scanner subassembly **32** is then repositioned to horizontal frame first end **164**. The above-described scan process is then repeated for all areas along weld **20**B accessible without moving inspection apparatus **22** relative to shroud **14**. Similarly, the described scan process is repeated for shroud welds between shroud top **16** and shroud bottom **18** without moving inspection apparatus **22** relative to shroud **14**. This scanning process is repeated until horizontal frame **118** reaches second end **30** of mast subassembly **26**.

Thereafter, inspection apparatus **22** must be repositioned to the next portion of shroud **14** to be scanned. Prior to moving, de-activation of air ram **116** releases kicker clamp **106**. Drive system **24** is then activated by remote motion control system (not shown) and drive assemblies **34**A, **34**B, **34**C and **34**D move inspection apparatus **22** relative to shroud **14**. Specifically, drive assemblies **34**A, **34**B, **34**C and **34**D are activated so that each drive wheel pairs **76** rotate causing inspection apparatus **22** to move relative to shroud **14**. As inspection apparatus **22** is moved, position encoders **148** integral with motors **142**, **146**, **68**, **160** and **162** provides movement information to remote motion control system (not shown). Inspection apparatus **22** is moved by a distance equal to the horizontal width of the first scan. After moving inspection apparatus **22** the appropriate distance, kicker clamp arm **106** is re-engaged to sidewall **12**. In one embodiment, horizontal frame **118** is then moved to mast subassembly first end **28** and scanner assembly **32** is moved to horizontal frame first end **164**. Thereafter, the above-described scan process implemented to conduct the first shroud portion scan is repeated for all additional shroud welds.

If, during repositioning of inspection apparatus **22**, drive system **24** encounters an obstacle, each drive assembly **34**A, **34**B, **34**C and **34**D is capable of being independently engaged or disengaged from shroud top **16**. For example, upon drive assembly **34**B encountering an obstacle, drive wheel pair **76** is disengaged from shroud top **16**. Specifically, air ram **78** is activated causing drive wheel pair **76** to rotate out of engagement with shroud top **16**. When the obstacle is passed, air ram **78** is de-activated causing drive wheel pair **76** to re-engage with shroud top **16**. With drive assembly **34**B disengaged from shroud top **16**, drive assemblies **34**A, **34**C and **34**D support the weight and move inspection apparatus **22** relative to shroud **14**.

In one embodiment, only two drive assemblies are engaged with shroud top **16** at any one time, for example **34**A and **34**D. Upon drive assembly **34**A encountering an obstacle, drive assembly **34**B is moved into engagement and drive assembly **34**A is disengaged from shroud top **16** as described above. Upon drive assembly **34**B encountering the obstruction, disengaged drive assembly **34**A is re-engaged to shroud top **16** as described above, and drive assembly **34**B is disengaged. Drive assemblies **34**C and **34**D are similarly engaged and disengaged to shroud **14** to avoid shroud top obstacles. Drive assemblies **34**A, **34**B, **34**C and **34**D are spaced so that only two of such drive assemblies are required at any time to support and move inspection apparatus **22**.

Upon scanning all portions of shroud **14**, inspection apparatus **22** is removed from RPV **10**. Specifically, kicker clamp **106** is released by de-activating air ram **116**. Inspection apparatus **22** is then raised from RPV **10** until mast assembly **26** is elevated above RPV **10** such that inspection apparatus **22** can be removed.

The above-described assembly facilitates inspection of a nuclear reactor shroud without requiring support from the refuel or auxiliary bridge. In addition, such apparatus avoids shroud top obstructions allowing examination of the entire shroud with a single insertion and removal of the inspection apparatus, therefore saving time.

From the preceding description of various embodiments of the present invention, it is evident that the objects of the invention are attained. Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is intended by way of illustration and example only and is not to be taken by way of limitation. Accordingly, the spirit and scope of the invention are to be limited only by the terms of the appended claims.

What is claimed is:

1. An automated inspection apparatus for inspecting shroud welds of a shroud in a reactor pressure vessel of a nuclear reactor, the shroud having a bottom flange and a top, the reactor pressure vessel having a sidewall, said apparatus comprising:

a drive system comprising a plurality of drive assemblies, a plurality of support frame members coupled to said drive assemblies, and a plurality of guide roller assemblies coupled to said support frame members, said drive system configured to movably engage the shroud top;

a mast subassembly coupled to said drive system; and

a scanner subassembly movably coupled to said mast subassembly, said scanner subassembly configured to inspect the shroud welds.

2. An inspection apparatus in accordance with claim **1** wherein each of said drive assemblies comprises:

a drive support channel member coupled to at least one of said support frame members;

a first and a second drive assembly support plate coupled to said support frame member on opposing sides of said support channel member; and

a wheel assembly comprising a drive wheel pair, said wheel assembly pivotly coupled to said support plates, said drove wheel pair configured to engage the shroud top.

3. An inspection apparatus in accordance with claim wherein **2** wherein said wheel assembly is configured to move between a first position, where said drive wheel pair engages the shroud top and a second position, where said drive wheel pair does not engage the shroud top.

4. An inspection apparatus in accordance with claim **2** wherein each said drive wheel pair comprises a first and a second drive wheel, said first drive wheel coupled to a drive motor and said second drive wheel coupled to said first drive wheel with a timing belt, wherein said first drive wheel and drive motor, and said second drive wheel is movably coupled to a wheel mounting plate, said wheel mounting plate movably coupled to said first and second support plates.

5. An inspection apparatus in accordance with claim **4** wherein said drive motor comprises an encoder coupled to said drive motor, said encoder configured to provide inspection apparatus position data.

6. An inspection apparatus in accordance with claim **1** wherein said scanner subassembly comprises a scanner and a horizontal frame, said scanner movably coupled to said horizontal frame, said horizontal frame movably coupled to said mast subassembly.

7. An inspection apparatus in accordance with claim **6** wherein said scanner subassembly further comprises a turntable rotatably coupling said scanner to said horizontal frame.

8. An inspection apparatus in accordance with claim **7** wherein said scanner subassembly further comprises a movable plate movably coupling said scanner to said turntable, said movable plate being linearly movable.

9. An inspection apparatus in accordance with claim **1** wherein said drive system further comprises a motor coupled to said scanner subassembly and configured to control a vertical position of said scanner subassembly.

10. An inspection apparatus in accordance with claim **9**, wherein said motor comprises an encoder coupled to said motor, said encoder configured to provide inspection apparatus position data.

11. An inspection apparatus in accordance with claim **1** wherein said drive system comprises four drive assemblies and three support frame members.

12. An inspection apparatus in accordance with claim **1** wherein said mast subassembly comprises a first end, a second end, a kicker clamp, and at least one roller foot, said first end coupled to said drive system, said roller foot coupled to said second end and configured to engage the shroud bottom flange, and said kicker clamp connected to said mast between said first and second ends and configured to move into engagement with the reactor pressure vessel sidewall.

13. An automated inspection apparatus for inspecting shroud welds of a shroud in a reactor pressure vessel of a nuclear reactor, the shroud having a bottom flange and a top, the reactor pressure vessel having a sidewall, said apparatus comprising:

a drive system comprising a plurality of drive assemblies, a plurality of support frame members coupled to said drive assemblies, and a plurality of guide roller assemblies coupled to said support frame members, said drive system configured to movably engage the shroud top;

a mast subassembly coupled to said drive system, said mast subassembly comprising a first end, a second end, a kicker clamp, and at least one roller foot, said first end coupled to said drive system, said roller foot coupled to said second end and configured to engage the shroud bottom flange, and said kicker clamp connected to said mast between said first and second ends and configured to move into engagement with the reactor pressure vessel sidewall; and

a scanner subassembly movably coupled to said mast subassembly, said scanner subassembly configured to inspect the shroud welds.

14. An inspection apparatus in accordance with claim **13** wherein each of said drive assemblies comprises:

a drive support channel member coupled to at least one of said support frame members;

a first and a second drive assembly support plate coupled to said support channel member on opposing sides of said support channel member;

a wheel assembly comprising a drive wheel pair, said wheel assembly pivotly coupled to said support plates, said drive wheel pair configured to engage the shroud top.

15. An inspection apparatus in accordance with claim **14** wherein said wheel assembly is configured to move between a first position, where said drive wheel pair engages the shroud top and a second position, where said drive wheel pair does not engage the shroud top.

16. An inspection apparatus in accordance with claim **14** wherein each said drive wheel pair comprises a first and a second drive wheel, said first drive wheel coupled to a drive motor and said second drive wheel coupled to said first drive wheel with a timing belt, wherein said first drive wheel and drive motor, and said second drive wheel is movably coupled to a wheel mounting plate, said wheel mounting plate movably coupled to said first and second support plates.

17. An inspection apparatus in accordance with claim **16** wherein said drive motor comprises an encoder coupled to said drive motor, said encoder configured to provide inspection apparatus position data.

18. An inspection apparatus in accordance with claim **13** wherein said scanner subassembly comprises a scanner and a horizontal frame, said horizontal frame movably coupled to said mast subassembly.

19. An inspection apparatus in accordance with claim **18** wherein said scanner subassembly further comprises a turntable rotatably coupling said scanner to said horizontal frame.

20. An inspection apparatus in accordance with claim **19** wherein said scanner subassembly further comprises a movable plate movably coupling said scanner to said turntable, said movable plate being linearly movable.

21. An inspection apparatus in accordance with claim **13** wherein said drive system further comprises a motor coupled to said scanner subassembly and configured to control a vertical position of said scanner subassembly.

22. An inspection apparatus in accordance with claim **21**, wherein said motor comprises an encoder coupled to said motor, said encoder configured to provide inspection apparatus position data.

23. An inspection apparatus in accordance with claim **13** wherein said drive system comprises four drive assemblies and three support frame member.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,169,776 B1
DATED : January 2, 2001
INVENTOR(S) : James Christopher Collins

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Claim 3, column 8,
Line 6, delete the first occurrence of "wherein".

Signed and Sealed this

Thirtieth Day of October, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer *Acting Director of the United States Patent and Trademark Office*